

## EVALUATION METHODOLOGY OF POLISH NATIONAL MULTIYEAR RESEARCH PROGRAMME IN THE AREA OF TECHNICAL SOLUTIONS – CASE STUDY

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**Abstract:** The article provides the results of the practical application of evaluation methodology in the *Development of Innovative Systems of Manufacturing and Maintenance 2004-2008* (PW-004) multiyear strategic research programme in the area of technical solutions. Findings from this study indicate the evaluation criteria and methods used at different stages and levels of evaluation – project, thematic area and the entire programme levels. The author indicates the importance of the evaluation process, which contributed to the achievement of the practical results in the programme. However, the author also underlines shortcomings of the methodology and identifies additional elements needed to make the evaluation methodology complex.

**Key words:** evaluation, strategic research programme, technical innovations, evaluation methods, evaluation criteria.

### Introduction

The development of knowledge based economy requires direct scientific research to the areas, which have the greatest influence on the economic and social development of a country (Asheim et al., 2007; Hsu et al., 2008; Hudson, 2011). Strategic research programmes are the foundation of the development based economy through the introduction of new technologies and advanced materials (Godin, 2003; Maskell, 2009; Smith, 2010). One of such programmes is the *Development of Innovative Systems of Manufacturing and Maintenance 2004-2008* (PW-004) – national multiyear strategic research programme, co-ordinated by the Institute for Sustainable Technologies – National Research Institute in Radom and executed by about 75 research institutions (i.e. universities, research institutes). The main objective of the Programme was to create the system conditions and generate technical and organisational innovative solutions in the area of advanced products and technology of production (Mazurkiewicz et al., 2009). As the PW-004 Programme was high-budgeted, therefore one of the essential elements of its realisation was the evaluation of the results due to the selection of the most efficient ways of management and the usage of the results of the Programme.

### State-of-the-art on the evaluation of strategic research programmes

Considering the specificity of strategic research programmes in the area of technical solutions supporting sustainable development of the economy and the amount of funds spent on them, the conduction of a systematic evaluation is fully justified (Rossi et al., 2004). The sector of advanced technologies is characterised by quick technological

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progress and changes on the market (Malecki, 1991; Giesko, 2009), and therefore it is essential to precisely assess technological products, mainly in order to verify their appropriateness to the needs of beneficiaries. With regard to the significance of innovative products in the economy, it is necessary to use the evaluation methodology for strategic research programmes (Ingwersen and Larsen, 2007), which would enable the assessment of not only strategic research programmes from the perspective of the efficiency of tasks undertaken, but also allow for a precise assessment of individual technological solutions developed in the programme.

The case studies taken into consideration in this study (Japan Science Technology Agency Office of Basic Research, 2007; Rezendes, 2014; Gamota et al., 2014; Performance Management Network, 2014; Avellan et al., 2002; Koponen et al., 2008; Henry and Leather, 2008; Arnold et al., 2008; TEKES, 2006; Polish Agency for Enterprise Development, 2010; Jacobsen et al., 2002) point out the use of standard evaluation criteria and methods (Table 1), which do not seem sufficient in relation to the assessment of strategic research programmes in the area of technological solutions supporting sustainable economic growth.

**Table 1. Criteria and Methods Applied in the Evaluation of the Identified Strategic Research Programmes**

Case study	Evaluation criterion	Evaluation method
Ex-ante evaluation		
Core Research for Evolutional Science & Technology in Japan	Relevance, appropriateness, efficiency, cost-effectiveness, competitiveness, utility, impact	Document analysis, direct interviews, expert panels
Advanced Technology Programme in the U.S.	Appropriateness, efficiency, cost-effectiveness, competitiveness, sustainability, impact	Document analysis, direct interviews, expert panels
Exploratory Research for Advanced Technology in Japan	Efficiency	Document analysis, direct interviews, expert panels, questionnaires
On-going evaluation		
Hydrogen Early Adopters Program in Canada	Efficiency, impact, threats, implementation, relevance, cost-effectiveness	Document analysis, direct interviews, media monitoring
Hydraulic Turbine Research Programme in Sweden	Efficiency, impact, threats	Document analysis, observation, direct interviews, discussion panel
Exploratory Research for Advanced Technology in Japan	Efficiency, impact	Document analysis, observation, direct interviews, statistic analysis, discussion panel
Mid-term evaluation		
Finnish Nanoscience and Nanotechnology Programme	Appropriateness, efficiency, impact, competitiveness, relevance, commercialisation level	Statistic analysis, on-line interviews
Premium Automotive Research and Development Programme in the UK	Appropriateness, efficiency, competitiveness, cost-effectiveness	Document analysis, observation, questionnaires, intervention logic, econometric model
Competence Centre	Appropriateness, efficiency,	Document analysis, statistic

Programme in Estonia	complementarity, impact, relevance, threats	analysis, direct interviews, observation, discussion panel
Ex-post evaluation		
Clean Surfaces in Finland	Relevance, appropriateness, efficiency, cost-effectiveness, impact, commercialisation level	Document analysis, direct interviews, SWOT analysis, discussion panel, questionnaires
Innovation Voucher in Poland	Efficiency, impact, utility, sustainability	Document analysis, statistic analysis, CATI interviews
Programme for Interdisciplinary Materials Research Consortia in Sweden	Efficiency, cost-effectiveness, impact, utility, sustainability, implementation	Document analysis, statistic analysis, direct interviews, CATI interviews

Evaluation programmes, which were analysed, consist of criteria used in the evaluation of monothematic research projects. The methods used most often were: document analysis, interviews, questionnaires, discussion panels and statistic analysis. The methodologies analysed did not however consider the elements relevant to the technological assessment of the products that have big significance to the economy.

### **Evaluation methodology of the Development of Innovative Systems of Manufacturing and Maintenance 2004-2008 (PW-004) multiyear strategic programme**

The evaluation system within the PW-004 Programme included the conduction of the evaluation: at the entire Programme level (*ex-ante* and *ex-post*), at the thematic areas level (*ex-ante* and *ex-post*) and at the project level (*ex-ante* and *periodical*) (Figure 1).

Within the PW-004 Programme three calls in the 2004-2008 period were announced. Each call concerned 10 thematic areas: knowledge transformation and technology transfer methods; high-tech products and devices; technologies of production and maintenance with the use of advanced technologies; nanotechnology in surface engineering; systems for the rationalisation of the use of resources in technical equipment production and maintenance processes; recycling and utilisation systems; systems counteracting technical threats and elimination of the results of disasters; technologies and methods for decreasing ecological nuisance of industrial processes of production and maintenance of machines and technical devices; methods and apparatus for product, process and technical security tests; methods and devices for the support of quality systems in production processes.

Evaluation system at the project level

Before the start of the realisation of the research projects, their concepts were evaluated. Based on the opinions of the experts, the Research Council of the PW-004 programme assessed the propositions of the projects and assigned them to the following categories:

- propositions accepted for realisation;
- propositions accepted partially (after the limitation of the thematic scope of the research project);
- propositions accepted conditionally (after the modification of some aspects in the proposal);

- propositions recommended for next calls;
- propositions rejected.

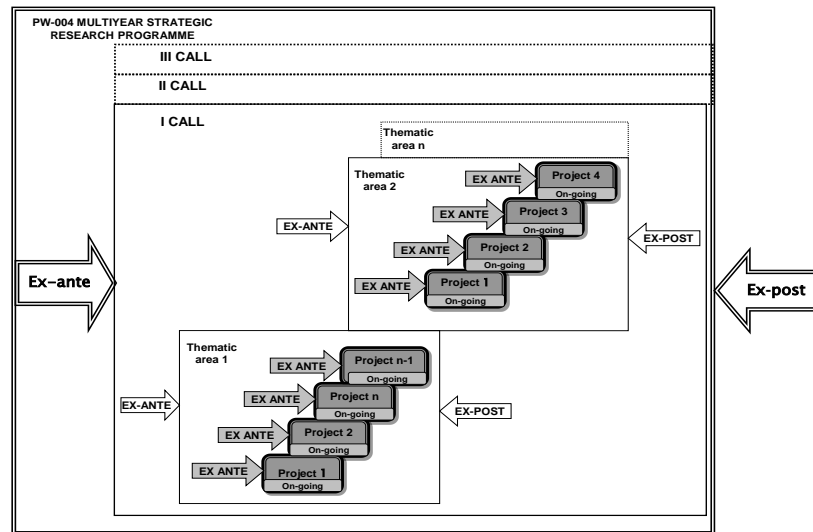


Figure 1. Evaluation system of the PW-004 multiyear strategic research programme

In the 1<sup>st</sup> call, the propositions of the projects were assessed with the criteria presented in Table 2.

Table 2. Criteria for the ex-ante evaluation in the 1<sup>st</sup> call

Evaluation criterion	Description
Relevance	Factual convergence of the projects with the subject-matter of the PW-004 Programme. Appropriateness of the proposed solutions to the actual directions of the scientific research.
Cost-effectiveness	Appropriateness of the costs to the planned scope of work.
Experience of the staff	Identification of the scientific experience of the staff engaged in the realisation of the project.
Innovativeness	Indication of the level of innovation of a proposed product.
Impact	Impact of the proposal on the economy, e.g. possibilities of the practical applications of the solutions not developed so far by the national scientific institutions.
Efficiency	Feasibility study, e.g. with the use of the proposed research methods, with the cooperation with the consortia of the scientific and industrial institutions.
Quantification of the results	Identification of the results planned to be achieved within the proposed project.

In the 1<sup>st</sup> call there were 129 projects submitted, out of which 47 were accepted for the realisation (22 of them – fully accepted; 25 – accepted partially). 20 propositions were recommended to be taken into account for next calls and 62 projects were rejected. In the case of the projects recommended for the realisation in the next calls, the reasons for not accepting them for current realisation were: partial relevance to the PW-004 Programme (20%), doubtful innovativeness of the results (4%), questionable impact of the results on the economy (20%), excessive costs (28%), low efficiency of realisation (12%), no material results identified (8%) and low factual explanation of the project (8%). The reasons for the rejection of projects were: lack of the relevance to the PW-004 Programme (28%), non-innovative character of the results (16%), lack of the impact of the results on the economy (21%), excessive costs (9%), impossible efficiency of realisation (17%) and the lack of the precision of the results (9%).

During the 2<sup>nd</sup> and 3<sup>rd</sup> calls, the *ex-ante* evaluation system was modified by changing the evaluation criteria (Table 3).

**Table 3. Criteria of the ex-ante evaluation during the 2<sup>nd</sup> and the 3<sup>rd</sup> calls**

Evaluation criterion	Scale		
	Full	Partial	Lack of relevance
Factual relevance with the PW-004 programme			
Efficiency of realisation (feasibility study)	High	Suitable	Uncertain
Cost-effectiveness	High	Average	Small
Scientific experience of the staff	High	Average	Low
Technical and human potential	Very good	Sufficient	Insufficient
Innovativeness level of the solutions	High	Average	None
Impact on the economy	High	Average	Uncertain
Scientific level of the solutions	High	Average	Weak
Quantification of the results	Prototype		
	Technology		
	Product		
	Method		
	System		
	Other		

In the 2<sup>nd</sup> call, there were 119 projects submitted, out of which 75 were accepted for the realisation (32 fully accepted and 43 accepted partially). Two (2) propositions were recommended for the next calls and 42 projects were rejected. In the 3<sup>rd</sup> call there were 110 projects submitted, out of which 72 were accepted for the realisation (28 fully accepted, 2 accepted partially and 42 accepted conditionally). 38 projects were rejected.

During the *ex-ante* evaluation of the projects in the PW-004 Programme, the following methods were used:

- document analysis including verification of all documents submitted by the applicants of the projects to the experts;
- expert panel that verified if the evaluation criteria were met;
- cost-effectiveness analysis enabling the verification of the relations between the results planned to be achieved and the costs assigned to them.

The *ex-ante* evaluation allowed for the decisions on the proper division of funds for the original technical solutions to be made, which contributed to the creation of new technologies and the use of the results in long-term perspective in the economy.

The PW-004 Programme assumed the conduction of the internal *periodical* evaluations for the particular projects undertaken within the Programme. Within the 1<sup>st</sup> call 5 periodical evaluations, within the 2<sup>nd</sup> call – 5 periodical evaluations and within the 3<sup>rd</sup> call – 8 periodical evaluations were conducted. The results of the projects were assessed by the internal and the external experts from the thematic areas relevant to the Programme. The executors of all projects were obliged to participate in systematic scientific seminars and to present the factual and financial aspects on the tasks undertaken. The assessment of the projects was conducted by the external experts, representatives of the Ministry of Economy, representatives of the Council of the PW-004 Programme and the project managers, and documented in the protocol. They assessed the research projects with the use of the evaluation criteria of efficiency, cost-effectiveness and implementation to the economy (Table 4).

**Table 4. Criteria for the periodical evaluation of the research projects in the PW-004 Programme**

Evaluation criterion	Description
Efficiency	The level of the achievement of the planned results with comparison to the schedule developed before the start of the realisation of the project. The analysis of the problems, the threats and the feasibility study or the indication of the barriers hampering the achievement of planned objectives.
Cost-effectiveness	The use of finances – if the funds are spent effectively, if they are spend according to the schedule designed before the start of the project, if the funds are sufficient.
Impact	Ways of transferring scientific achievements into practical solutions.
Innovativeness	The level of originality of the solutions.

The methods used in the *periodical* evaluations included the expert panel and the discussion panel with the team working on the technological products. In the case of any problems with the realisation of the projects, the experts supported the executors on how to correctly realise the tasks in the project. The problems were verified during next *periodical* evaluations.

Evaluation system at the thematic area level

The thematic areas were evaluated *ex-ante* and *ex-post*. The *ex-ante* evaluation was conducted by the Commission called up by the coordinating institution and the evaluation criteria are presented in Table 5.

The evaluations of the efficiency and the complementarity of the thematic areas were conducted by external experts, commissioned by the coordinating unit. The method used at this step was the expert panel. The evaluation at the thematic area level enabled the rejection of some of the projects, which were initially accepted partially or conditionally for the realisation.

**Table 5. Criteria for the ex-ante evaluation of the thematic areas in the PW-004 Programme**

Evaluation criterion	Description
Efficiency	Verification of the likeability of a successful finish of the realisation of the projects.
Complementarity	Verification of the coherence of the projects with other projects existing within the thematic area.

The *ex-ante* evaluation at the thematic areas enabled to introduce changes regarding the number of the accepted and rejected propositions of the research projects before their start.

After the completion of the Programme, the thematic areas were evaluated *ex-post* by the external experts. The evaluation had a very general character, enabling to state if the realisation of the whole research area was a success or not.

Evaluation system at the entire Programme level

The evaluation of the whole Programme conducted before its start was done by the external experts indicated by the institution financing the Programme. The external experts evaluated the Programme with the same criteria taken into consideration as in the case of the evaluation of the thematic areas.

After the completion of the PW-004 Programme, the external (very general) *ex-post* evaluation of the entire Programme was conducted. It was carried out by the members of the Research Commission for the Development of the National Economy and the representatives of the Ministry of Science and Higher Education. The *ex-post* evaluation aimed at the assessment of the final reports of selected research projects undertaken within the PW-004 Programme. The criteria used in the assessment are presented in table 6.

**Table 6. Criteria used in the external ex-post evaluation of the entire PW-004 Programme**

Evaluation criteria	Description
Relevance	Appropriateness of the Programme subject-matter to national strategic directions.
Implementation level	Level of implementation of the solutions into practice.
Scientific value of the Programme	Identification of the solutions developed in the research projects within the PW-004 Programme, with empirical and utilitarian values taken into consideration. Level of the cooperation with the scientific units.
Utility	Identification of the aspects supporting national sustainable development.
Sustainability	Identification of possibilities of continuing the research within the theme of the PW-004 Programme.

The research method used in the *ex-post* evaluation was the expert panel composed of the members of the Research Commission for the Development of National Economy and the representatives of the Ministry of Science and Higher Education. The first step of the procedure was to identify the objective and the scope of the evaluation. Afterwards, the chairman of the Commission presented the results of the assessment of selected projects undertaken in the Programme. The possibilities



of practical application of the solutions were indicated and the wide participation of the scientific units was underlined. The last step of the evaluation was to develop the recommendations on the need for undertaking similar initiatives in the future and the launch of a new “*Innovative Technical Support Systems for Sustainable Economic Development*” Strategic Research Programme (2010-2015), which is at this moment under the realisation. In this new programme the evaluation methodology of the PW-004 Programme is used and enriched.

The *ex-post* evaluation of the PW-004 multiyear strategic research programme indicated the relations between the thematic scientific areas of the Programme and the national strategic directions and the need of the generation of the research projects with the similar subject-matter.

### **Concluding remarks**

As a result of the PW-004 programme, 327 new solutions were developed (59 patented), including: 142 original apparatus solutions (mainly machines and devices), 111 production technologies and 74 original system solutions (among others control and automation systems) and more than 300 articles in national and international journals were published. What is more, the method for the verification of the implementation maturity level of the technical solutions (SDW) was developed (Mazurkiewicz et al., 2010), which is currently being verified and modified within the “*Innovative Technical Support Systems for Sustainable Economic Development*” Strategic Research Programme.

The realisation of the national PW-004 programme was a success, however the evaluation process was based only on the experience of the management staff who did not use the complex methodological approach. There was no methodology for the selection of the evaluation type to the programme level. The evaluation operations were only concentrated on the scientific and the technical levels of the solutions and their applicability, but there was a lack of tools enabling precise assessment of technological solutions developed in the programme, among others, the implementation maturity level, the innovativeness level, the implementation risk and the commercial potential. Evidently, the innovativeness was one of the criteria of the evaluation process, however the specific method for the measurement of the aspect was not applied.

In order to successfully evaluate the forthcoming strategic programmes, it seems reasonable to design a complex methodology, which would enable the identification of many aspects as the assessment of technological solutions considering among others innovativeness, implementation maturity and commercial potential aspects and the decision making on the introduction of changes within the tasks undertaken.

The complex methodology should have a multi-level structure, enabling the conduction of the evaluation on selected levels of the strategic programme and engaging the management staff, the internal experts, the external experts and the authors of technological solutions in the evaluation process. Moreover, the methodology should have an open character enabling the consideration of additional elements, if needed, or the rejection of some of them.



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## METODOLOGIA OCENY POLSKIEGO NARODOWEGO WIELOLETNIEGO PROGRAMU BADAŃ W DZIEDZINIE ROZWIĄZAŃ TECHNICZNYCH - STUDIUM PRZYPADKU

**Streszczenie:** W artykule zaprezentowano wyniki praktycznego zastosowania metodyki ewaluacji w ramach krajowego wieloletniego programu strategicznego w obszarze innowacji technicznych *Doskonalenie systemów rozwoju innowacyjności w produkcji i eksploatacji w latach 2004-2008* (PW-004). Wskazano kryteria i metody zastosowane na różnych etapach i poziomach ewaluacji – poziomie projektu badawczego, poziomie grupy tematycznej oraz poziomie programu strategicznego w ujęciu całościowym. Autor podkreśla istotę procesu ewaluacji, którego wyniki przyczyniają się do osiągnięcia praktycznych rezultatów zaplanowanych w programie. Jednakże, wskazuje również na braki w metodyce i identyfikuje dodatkowe elementy niezbędne do wprowadzenia, aby ewaluacja uzyskała charakter kompleksowy.

**Słowa kluczowe:** ewaluacja, strategiczny program badawczy, innowacje techniczne, metody ewaluacja, kryteria ewaluacja.

### 波蘭國家評估方法長的節目在研究技術解決方案領域 - 案例研究

**摘要：**本文介紹了評價方法創新製造系統開發和維護的實際應用，在2004-2008年（PW004）科學研究的技術解決方案領域的多年度戰略計劃的結果。研究結果表明，在不同的階段和評估水平所使用的評估標準和方法該項目，主體區和整個節目的水平。作者指出的評估過程，這有助於實現該計劃的實際成果的重要性。不過，筆者也強調該方法的缺點，並確定必要的額外的元素，創造一個複雜的評估方法

**關鍵字：**評估，戰略研究計劃，技術創新，評價方法，評價標準